Identifying quality in teacher-education students' models of self-regulation processes in learning: A case study

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Introduction

In recent years a number of researchers have raised concerns about the quality of tertiary students' knowledge of learning. Although Elen and Lowyck (1999) observed a range of relevant professional knowledge in their undergraduate education students, they found that the students lacked systematic vocabularies about instruction and did *"not seem to have articulate conceptions about the way in which an instructional environment may support their cognitive processing and/or control activities" (p. 157).* Woolfolk-Hoy and Tschannen-Moran (1999) worried that the prospective teachers they studied lacked

> *understanding of the connections between teaching strategies and students' learning ... our students have great difficulty explaining the mechanism of learning and how teaching influences these processes ... Few students are able to connect the activity to cognitive processes that lead to learning (p. 280-281)*

In our recent research we have also been concerned that some of the teacher-educations students we have interviewed did not find it easy to describe their knowledge of learning in an explicit manner (Lawson, Askell-Williams & Murray-Harvey, 2003). Like Elen and Lowyck (1999) we found that many students did not use the technical language of contemporary learning theory and frequently responded that they had not reflected on the processes involved in their learning in any systematic manner. The current report includes a further analysis of students' knowledge of learning in which we attempt to develop a more precise understanding of the state of this knowledge. The analysis in this report focuses on one student's interview responses to identify knowledge about self-regulation processes in learning and the quality, or degree of development, of this knowledge. Our analysis of the quality of knowledge is focussed on the structure of the student's knowledge schemas and the complexity of the relationships he expressed among these schemas.

Knowledge of learning as a domain of knowledge

Teacher education students need knowledge in a number of domains (Munby, Russell, & Martin, 2001; Putnam & Borko, 1997; Shulman, 1986). One of these domains is the domain of learning. Teacher-education students need this knowledge for two related purposes: They will use it in their own learning and they will use it when they help their own students to develop knowledge about learning. In the classroom teachers must not only be able to help a student when that student asks to be shown how to solve a particular problem. A teacher must also be able to help the student to learn in a way that will allow that student to solve different but related problems, and perhaps problems in a different area of the curriculum. In other words the teacher must work with students in a way that will allow them to bring about transfer of their knowledge, preferably transfer across a significant distance (Bransford, Brown & Cocking, 2000). If such transfer is to eventuate, teachers will need to help students to develop sophisticated knowledge of motivational, cognitive and metacognitive processes in learning (Mayer, 1998). Put another way, to effect substantial transfer, both teachers and their students will need to have a good understanding of contemporary learning theory.

Self-regulation models of learning

We have focussed the current investigation of knowledge of learning on self-regulation processes because the self-regulation framework includes sets of processes that are of central interest in learning. In doing this we are sampling the knowledge of learning of our prospective teachers, making the assumption that such a sample will provide a good estimate of their knowledge about learning.

Descriptions of self-regulation frameworks have been provided by several groups in research on instructional psychology (e.g. Schunk & Zimmerman, 1998; Winne, 1995). In his model of self-regulation, Zimmerman (1998) describes learning as a cyclical activity that involves three phases: Forethought, performance or volitional control, and self-reflection. These phases may be thought of as involving processing prior to the transformation of information, transforming activity itself, and processing that is concerned with evaluation of the outcomes of the transforming activity. The specific events involved in these phases include emotional, motivational, cognitive, metacognitive and situational components. An objective for the current study was to describe the range of the teacher education student's knowledge of self-regulation processes using Zimmerman's three-phase framework. Although a listing of the content of a student's knowledge on a topic may be seen to be as a quantitative indicator, breadth of knowledge does also have a qualitative component.

Quality of knowledge

Researchers have addressed issues of quality of knowledge from different perspectives, using different descriptors (e.g., depth of processing; levels of outcomes; connectedness; complexity, elaboration). Problems have been associated with each of the terms favoured within those different perspectives. For example, Jacoby and Craik (1979) pointed out that "some difficulty has been encountered in specifying exactly what is meant by 'deep' and 'meaningful'" (Jacoby & Craik, 1979 p. 1). Twenty years later the same problem was raised in Mintzes and Novak's (1999) analysis of 'understanding'.

The varied perspectives on knowledge quality have arisen as researchers have focussed on different dimensions of quality. When Biggs and Collis (1982) addressed the question of identifying quality in students' learning outcomes, their SOLO taxonomy included dimensions such as capacity of memory, relatedness of constructs, and conceptual abstraction and extension beyond the instructional material given. White and Gunstone (White, 1979; White & Gunstone, 1980) took an even more multi-dimensional perspective on the qualities of cognitive (memory) structure. White's (1979) dimensions were 1) extent, 2) precision, 3) internal consistency, 4) accord with reality, 5) variety of types of memory element, 6) variety of topics, 7) shape, 8) ratio of internal to external associations, and 9) availability.

Other researchers have focussed upon a dimension of knowledge relatedness, or connectedness, when addressing knowledge quality (e.g., Mayer, 1975; Nuthall, 2000a; White & Gunstone, 1992). Recently, Hogan and her colleagues (Hogan, 1999a; Hogan, 1999b; Hogan & Fisherkeller, 1999; Hogan, Nastasi, & Pressley, 2000) produced a series of papers that documented eighth grade students' depth of cognitive processing and reasoning complexity. To assess students' reasoning complexity

Hogan et al. created a rubric containing six criteria: generativity, elaboration, justifications, explanations, synthesis and logical coherence.

In her analysis of this broad array of literature on quality of learning, Askell-Williams (2004) identified five categories of quality that incorporated the distinctions made in the literature noted above. Her categories were: (1) well-foundedness, which considers the conceptual status of the knowledge in relation to current understanding in the field of learning research; (2) structure, which identifies the configuration of schemas included in the knowledge domain; (3) complexity, which characterises the way that relationships among schema are represented; (4) representation format, which describes the different ways in which knowledge can be represented; and (5) context, which identifies the situational characteristics of the knowledge representation. We have focussed the current analysis of the quality of knowledge of self-regulation on the structure and complexity categories in Askell-Williams' framework.

Structure

A central assumption of contemporary cognitive science is that 'having' knowledge implies that it is structured in some form (Rumelhart & Ortony, 1977; Shank & Abelson, 1977). Labels for the structured representations vary between research programs, but it is common for the "packets of integrated information" (Hunt, 1993, p. 530) to be referred to as schemas, or schemata. When viewed at a larger grain size, a network of schemas can be thought of as mental spaces, structured "conceptual packets constructed as we speak, for purposes of local understanding and action" (Fauconnier & Turner, 1998, p. 137). In a cognitive constructivist perspective, schemata are described as being organised structures of knowledge components, including those structures that are closely tied to specific situations and events (Derry, 1996). Robinson, Even and Tirosh (1992) adopted a similar line of thinking to us when they suggested that in order to understand the depth of teachers' knowledge and understanding it was necessary to examine the network of interconnected schemas and procedures that form their knowledge base.

Mayer (1975) made use of the notion of connectedness in his description of the accumulation of new information in long term memory as adding new 'nodes' to memory and connecting the new nodes with components of the existing network. He utilised this nodes-network framework to examine learning outcomes along three dimensions. In two of these dimensions, the notion of connectedness was employed to evaluate prerequisite knowledge and the activation of assimilative knowledge structures. *Internal connectedness* refers to the degree to which new nodes of information were connected with one another to form a single well-defined structure. Mayer referred to the degree to which new nodes of information were connected with information already existing in the learner's cognitive structure as *external connectedness*.

The representation of a knowledge base as a connected schema network structure provides direction for examining the structure of knowledge about learning. In this paper we focus our analysis of structure at a relatively large grain size, with the focus being on representation of the knowledge elements identified by the participant as being related to the procedure argued to be most important for his learning. The outcome of this analysis is a mapping of these knowledge elements and identification of the student's *mini-theories* about learning.

Complexity

In a connected knowledge structure the nature of the connections between the parts of the structure is of critical importance. The complexity of relationships is a key element in descriptions of understanding in terms such as 'depth'. The approach we have taken to analysis of complexity is to examine the explanation made by the participant of the relationship among parts of a schema, or among different schemas. These explanations emerged when we asked the participant to identify what most helped him to learn in his university classes and then to explain in detail how the identified procedure helped his learning. These explanations then became the focus of the analysis of complexity.

Ideas taken from several threads of argument have been used to inform our understanding of differences in quality of explanation. Karmiloff-Smith (1992) used the broad distinction between implicit and explicit knowledge to identify four levels of knowledge representation. The basis for the change in level in Karmiloff-Smith's model is a process of representational redescription, which moves an initially narrowly bound, implicit and external representation that is limited to successful performance, through the next level of internal representation which is not available for conscious access, then to an explicit representation that is available for conscious access, and ultimately to a representation that can be the subject of verbal report and discussion. The most advanced level of representation should also be the one at which knowledge is most precise and most technical in nature.

The category of implicit knowledge in Karmiloff-Smith's model is very similar to the notion of tacit knowledge taken up in the work of Schon and Sternberg. Schön (1988) used the phrase 'knowing-in-action' (p. 25) to describe the tacit knowledge that is embedded in intelligent, spontaneous, skillful action. Sternberg (2000) identified three features of tacit knowledge, 1) that it is acquired with little or no environmental support, 2) that it is procedural, and can be represented on the form of context-specific, condition-action (if–then) pairings, and 3) it is practically useful. By definition, tacit knowledge may not be available in an explicit, verbal form. To the extent that actions are successful, it may not be necessary to make the implicit knowledge that underpins them explicit (Schön, 1988). However, if actions are less than optimal, or if previously successful methods of approaching situations no longer work due to changing circumstances, then it is necessary to enter into a process of reflection. In order to engage in reflection, tacit knowledge needs to be made explicit. The requirement to explain our views challenges us to make knowledge explicit.

Schön differentiated between two broad kinds of reflection, namely reflection-in-action and reflection-on-action. The point of differentiation between the two kinds of reflection is timing. With reflection-in-action, the person apprehends a difficulty in the execution of a task, and through relatively immediate reflection and adjustment, is able to make modifications that will improve the concurrent performance of the task. In reflection-on-action, the task is already complete, and so improvements to that episode cannot be made. However, reflection-on-action can be made in order to improve future task engagements. Furthermore, it is possible to reflect-on one's previous reflection-in-action. Indeed, "several levels and kinds of reflection play important roles in the acquisition of artistry" (Schön, 1988, p. 31)

Learning is an action with which teacher education students are well acquainted. Some of what is known about processes of learning will have been the subject of explicit instruction and environmental support: it will therefore be represented in a declarative form. However, much of a learner's knowledge about learning is, no doubt, tacit. Schön's analysis suggests that significant gains in the quality of learning actions will be made if a learner's tacit knowledge about learning is able to be made explicit, thus permitting both reflection-in-action and reflection-on-action. Particularly in the case of teacher education students, who are both learners and prospective teachers of other learners, reflecting in, and on, actions associated with learning could be considered an essential requirement for developing what Schön refers to as "professional artistry" (p. 33). Reflection enables the practitioner to "respond to the unexpected or anomalous by *restructuring* some of her strategies of action, theories of phenomena, or ways of framing the problem" (Schön, 1988, p. 35). This description of artistry can also be seen as an alternative description of successful transfer of knowledge to a new problem situation.

A close parallel can be drawn between Schön's conceptual 'restructuring' through reflection, and Karmiloff-Smith's (1992) model of levels of representational redescription. Other researchers have also posited different levels of cognitive representation, with higher levels requiring knowledge restructuring. For example, Martin, Mintzes and Clavjo (2000) found that students moved between *plateaux* of collecting numerous pieces of knowledge and *gradients* where the students integrated the knowledge into conceptual frameworks. And earlier, Shuell (1990) described the nature of the learning process itself as being composed of three phases, 1) initial accretion of facts using relatively simple forms of learning; 2) intermediate development of structures and networks, experimentation, reflection and generalisation; and 3) terminal integration, functionality, automaticity and relative effortlessness. In the terms used by Bereiter (1997), to make progress in understanding the learner must engage in a continual process of abstraction from the existing level of understanding.

The final thread of argument that has informed our analysis of complexity of explanations is the notion of generative power. Mayer (2003) described 'generative activities' that help the learner to integrate newly presented information with existing knowledge. Wittrock (1989) described comprehension as a generative activity involving the "active construction of relations" (p. 349), and generative teaching as "knowing how and when to facilitate the learner's construction of relations" (p. 353). In Wittrock's analysis, a teacher needs to have access to strategies that will mediate such facilitation of students' generative processing. Implicit in Wittrock's account is the expectation that the accessed knowledge should have what Bruner (1966) referred to as *power*. For Bruner, a powerful form of representation is one that enables a learner to generate solutions to a wider range of problems, so that a powerful knowledge representation will allow "a learner, to connect matters, that on the surface, seem quite separate"(p. 48). Use of the term generative power provides a way to establish a qualitative dimension in the facilitative actions described by Wittrock and Mayer. It also represents a way of describing an important set of expectations that we hold for our teacher education students, namely, the potential of their knowledge bases to generate actions that facilitate their own and their students' learning.

In this report we have first undertaken a detailed description of the knowledge of self-regulation processes in learning reported by one teacher education student and have examined the structure and complexity of that knowledge. In addition we have reported the results of related analyses involving a group of 10 teacher-education students who participated in interviews.

Method

Participants

The 10 participants were students in the final semester of their final year of the junior primary, primary, middle school and secondary strands of the Bachelor of Education (B Ed) program in an Australian university. The participants first provided short responses to a question that asked them to describe what helped them to learn in their university classes. Subsequently they participated in individual interviews. All participants had undertaken at least 80 days of supervised practical teaching experience in schools and comprised a mix of mature age students and those aged in their early 20s. The analyses reported here include both detailed analysis of the data of one participant and of data provided by the larger group. The case study participant, referred to Sam, was a graduate-entry student to the junior primary/primary strand, with a science background who graduated with a GPA slightly above a credit level.

Procedure

Participants were involved in the study on two occasions. On the first occasion students completed a short response to a question that asked them what helped them to learn in their university classes. Subsequently 10 students participated in an interview that focussed on their written response in occasion 1, asking them to select the statement that was is most important in terms of helping them to learn in their university classes and then to respond to questions that probed their understanding of how specific actions or procedures helped them to learn. The interviewer asked the student to expand on the meaning of statements, to give examples, to explain the effect on learning, to explain what part of the learning process was affected, and how this effect occurred. Students were invited to use any form of explanation they thought helpful and were encouraged to express any of their theories of how learning was affected. The sequential probing of terms used by the students in their explanations was designed to 'follow' the student's knowledge access path as they provided explanations. Thus if a student explained that class discussion helped her to "bounce ideas off others" she was asked to explain what 'bouncing off' involved and how that helped her learning. The probes were designed to follow through the knowledge connections established by the student that related to their nominated procedures. The probing ended when the student could generate no new information. Interviews ran for approximately one hour.

Coding of data

The transcript of Sam's interview was coded in a number of ways. First, we were interested in describing the self-regulation content provided by the students and so coded the transcript for instances of self-regulation using the three phase model of self-regulation described by Zimmerman (1998). Figure 1 shows an excerpt of a map of the coding of Sam's transcript for statements of instances of self-regulation. The vertical positioning of the boxes on the map indicates the sequence of statements. For this report, the analysis has been restricted to the initial section of the interview in which the participant discussed the procedure that was selected as most important for helping learning. Output from this analysis was used to provide a list of statements of self-regulation processes.

A second form of coding of the transcript was directed at providing data for the analysis of structure and complexity. A section of output from this form of analysis is shown in Table 1. The statements in this representation identify the processes or procedures identified as helping learning, any elaborations on those statements, or explanation of the way in which the process or procedure assisted learning. These elaborations or explanations were entered into boxes to the right of the procedure.

This analysis facilitated identification of segments of the transcript that were concerned with the same topic. These segments were identified as "mini-theories" of a particular process or procedure.

This data representation was also used to code for complexity of explanations of how processes or procedures helped the student's learning. The explanations were categorised into one of four levels of complexity. As shown in Table 2, the levels move from mere statement of an effect (Statement), to elaboration of that effect (Elaborated Statement), to recognition of an implication of the effect for an affective or cognitive component of learning (Implication), and finally to a level where the effect is explained with reference to a model or construct that is explicitly related to a component of contemporary theory of learning (Explicit Theory). In this report the frequency of explanations in each level in Sam's transcript was computed as a percentage of the total statements.

An additional category of statement was identified in this analysis. This recorded the Theory Negative statements in which the participant made a statement to the effect that a requested theoretical description of a process or procedure could not be provided. These statements were identified separately in order to recognise explicit negative reactions to expression of learning theory in technical terms.

Technical vocabulary analysis

We have argued above that as knowledge moves through the levels of redescription and increasing complexity, they become more precise or more differentiated. One index of precision is the vocabulary used in descriptions of knowledge. It is for this reason that we have been interested in the use of the technical vocabulary of contemporary theory of learning. Other things being equal, the use of the technical vocabulary in a domain should allow the user to make more precise differentiations within that domain. One possible impact of that degree of precision is that more powerful models of learning processes could be developed. The complete interview transcripts for all 10 participants were searched for use of a set of technical terms (and closely related terms) associated with Zimmerman's model of self-regulation, and for other key theoretical terms. This content analysis also involved identification of the students' use of related terms that could be seen as more general, common language translations of the technical vocabulary. A simple frequency count was made for the occurrence of these terms.

Results

Knowledge of self-regulation processes

The list of terms associated with self-regulation processes in Sam's transcript is shown in Table 3. This student did identify quite a lot of activity that can be categorised as being concerned with self-regulation processing, in each of the phases of Zimmerman's model, with the performance/volitional control phase showing the most frequent activity.

In terms of Zimmerman's comparison of naïve and skilful self-regulators, the evidence of Sam's forethought activity suggests that his goals are not low quality goals. He seeks understanding, looks beyond the given information and attempts to understand the perspective of lecturers and fellow students. His goal orientation therefore appears to be closer to mastery than to performance. With one notable exception he seems confident that he can achieve an understanding that will give him workable knowledge. The exception to this generally high level of self-efficacy is his view of his knowledge of learning, indicated by the several denials he made of his ability to provide any theoretical account of his self-regulation activity.

In the performance/volitional control category Sam has a range of different procedures for self-instruction: he listens, checks, interprets, slots in, judges, questions, uses feedback. So here he is also closer to Zimmerman's category of skilful self-regulator. However, almost all the performance descriptions are general and in everyday language. There is little explicit representation of his knowledge in explicit theoretical terms, though again quite a lot of vocabulary that could be readily used with reference to a more coherent model of learning.

Sam does report quite an amount of reflective activity. He evaluates his understanding against standards and makes some reference to affective concerns. He has a strong belief in his general approach to learning. There is no mention of processes of attribution in this interview.

On the basis of this brief analysis using Zimmerman's (1998) criteria there is evidence that would justify placing Sam toward the skilful end of Zimmerman's naïve-skillful continuum. The issue of the quality of this activity will be taken up in the next sections of the report.

Structure

Sam's discussion of what affects his learning is a connected structure. He enunciates major propositions about what affects his learning and elaborates on these with related propositions. For the topic that he chose as being most important in helping his learning, the analysis reported in Table 3 allowed identification of several groupings of propositions that we have labelled mini-theories. Two of these are shown in Table 4. The indented format of representation in this table is intended to represent the nesting of minor propositions within the major propositions expressed about the effect of discussion and about the nature of Sam's learning style. These two mini-theories are coherent structures, in which the relationships between major and related propositions are made explicit.

In Figure 2 the structure of these mini-theories is represented in a network diagram. The lines in the diagram represent relationships that Sam expressed between the knowledge elements. It is noteworthy that there are links drawn between different sections of the diagram: He linked the discussion and learning style mini-theories outlined in Table 3 and the 'slotting in' and 'exploration' sections of the discussion mini-theory. In Mayer's (1975) terms, this diagram shows evidence of connectedness within and between schemas. There is however, no higher level concept of a learning process that shows a level of abstraction from these mini-theories.

Complexity

The results of the coding of Sam's transcript for levels of complexity are shown in Table 5. A little over half of the statements of explanation in the transcript were evenly distributed between the two implicit knowledge categories. In the context of an interview where Sam was being pressed to be explicit about his knowledge of learning, we had expected that more of the statements would be coded at explicit levels. Almost 40% of his explanations were coded as explicit, most identifying cognitive, metacognitive, affective and situational implications of his self-regulatory activity. Finally, little of his explanation used formal, technical language of contemporary learning theory. It is also relevant to note that there were explicit theory negative statements in his transcript, with Sam, indicating that it was unusual and difficult for him to provide any sort of formal theoretical account of processes involved in learning.

Technical vocabulary

The results of the content analysis of terms related to both Zimmerman's model of self-regulation and other theoretical terms is shown in Table 5. There was very little use of the technical language of either self-regulation or other parts of contemporary learning theory. Although our earlier analysis of Sam's transcripts suggested that he used a large number of statements that signalled self-regulatory activity, the lack of use of technical labels for this activity suggests that he has not yet represented these activities in terms of a coherent and precise theory. The results in Table 5 suggest that the same conclusion can be made for the other students who took part in the interviews.

In the larger group more students made use of the common terms that were chosen as translations, even though the use of some of the common terms was still not extensive. One student developed a lengthy discussion of imagery and all 10 students developed ideas about a wide range of features of collaboration and interaction with other students, even though none made mention of the idea of a learning community. The technical vocabulary related to self-efficacy and attribution of cause associated with contemporary treatments of motivational knowledge (e.g., Winne, 1991) was absent from the student interviews, even though all students made reference to causal factors that influenced their learning.

The contrast in the use of the two sets of vocabulary related to motivation is of particular interest. Although all students referred to causes for learning outcomes they did not show evidence of familiarity with more sophisticated analyses of causal attributions. None referred to the productive analysis of attributional patterns derived from the work of Weiner (1979), even though this analytical framework was discussed in course readings. There was also low frequency of use of terms associated with metacognition and imagery. The difference in frequency of use of the technical and common language terms suggests that although most students in this group had recognised the importance of these components of learning at a general level, their technical vocabulary had not been developed toward differentiation into the more specific categories that would support precise analyses of relevant learning and teaching actions that would characterise Level 4 explanations.

Concluding discussion

The analysis we have carried out of knowledge in the domain of learning raises both concerns and possibilities.

Our results from both the case study and analysis done thus far with the larger group of interviewees suggests that the concerns raised by Woolfolk-Hoy and Tschannen-Moran (1999) and Elen and Lowyck (1999) might well apply to prospective teachers in our local context. The diffidence evident in Sam when he was asked to proffer theoretical accounts of parts of learning, and the low incidence of use of technical vocabulary suggests that his knowledge about learning is not high developed in a qualitative sense. If this is indeed the case then it seems that there will be less likelihood of his being able to respond in an effective way to his students' requests to help them to learn to solve problems in a way that will result in far transfer of knowledge.

With respect to the infrequent use of technical vocabulary we are in a quandary. On the one hand, some of our colleagues who do not profess expertise in learning theory raise doubts about whether this is a real problem for students. On the other hand we are regularly impressed by the frequent use of technical vocabulary by our teacher-education students when they discuss their biology, or art, or history. By the time these students have completed major sequences in these disciplines they have very well-developed technical vocabularies that enable them to make quite fine-grained differentiations when discussing issues and phenomena in those disciplines. They use their technical vocabulary to good effect in their explanations they provide to their own students. Why do we not expect a similar use of technical language when they are addressing issuesin the domain of learning? Why is it OK for teacher-education students to be embarrassed when challenged to discuss a theoretical account of an instance of learning? We would not expect the same reaction if we asked our biology students to discuss photosynthesis, or our art students to discuss cubism.

On balance we think that the stark contrast between the development of technical vocabulary in other domains and the domain of learning does represent an important problem. The problem is of real concern to those of us who design teacher education programs. We are of the view that we must try to make students' representations in the domain of learning more explicit so that they have the characterisitics of Karmiloff-Smith's (1992) third and fourth levels of re-representation.

This may not be easy but we do see interesting possibilities for proceeding in the pattern of results in this study. The analyses of Sam's transcript reveal a rich vein of knowledge about important processes in learning. Sam not only has a considerable quantity of knowledge related to forethought, performance and self-reflection but this is structured in a manner that gives it reasonable generative power. Such a body of knowledge could be exploited to good effect in our teacher-education classes. On the basis of Askell-Williams' (2004) findings on the knowledge of learning held by school students, similar use could be made of the mini-theories of students at earlier levels of education.

If our analysis is close to the mark there is a challenge for us in our teacher-education programs to work out how the technically precise language of learning can be acquired in a manner that will support the representational redescription of knowledge of learning. As noted earlier, Bereiter (1997) indicated that we must make it possible for students to engage in processes of abstraction, so that what is a set of observations becomes a mini-theory, which is then able to be related to other mini-theories in a higher level theoretical representation.

Finally, we suggest that there is promise in the approaches we have taken in addressing the difficult task of making statements about the quality of knowledge. We have looked at a restricted set of indicators in this report but they do allow us to gain more understanding of the degree of development of students' knowledge in the domain of learning. We hope that this task of analysing the quality of knowledge will attract further interest.

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Figure 1. Excerpt of map of coding of transcript for instances of self-regulation processes.

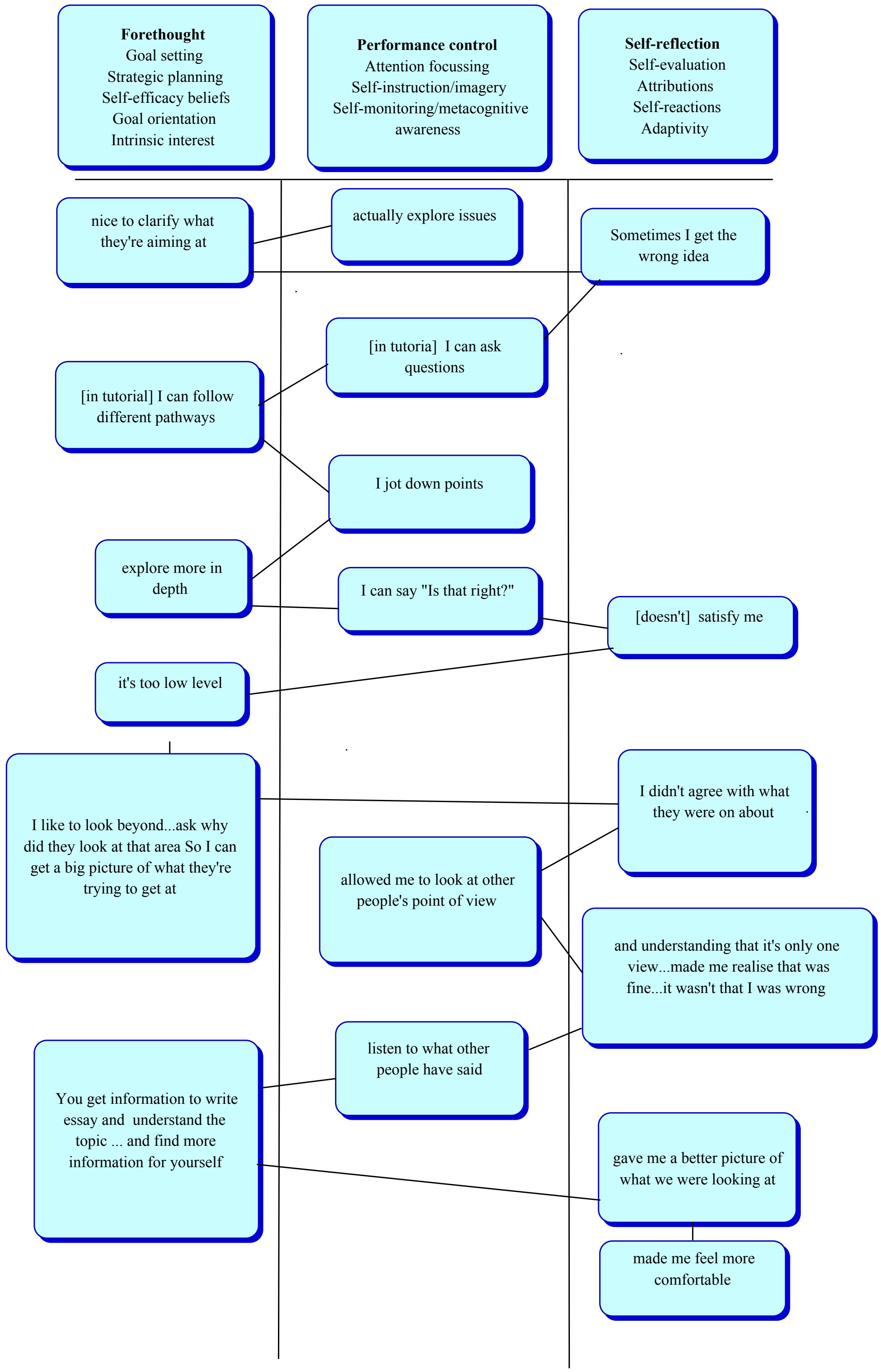

Table 1. Section of coding sheet for identification of self-regulation processes and explanations.

Topic helps learning by	Process or procedure	Elaboration or explanation	Elaboration or explanation	Elaboration or explanation	Elaboration or explanation
	it's good that we go over the lectures				
	explore issues				
	clarify what they are trying to aim at				
	it's a good way to introduce				
	it's a good way to ask questions				
	it's a good way follow different pathways				
	it's a good way find out what they're trying to teach				
(learning processes occurring)	jot down points I want clarified				
I can	explore questions				
	check understanding				
	look beyond				
	see why they are discussing that, why from that angle	I can get a big picture of what they are trying to get out of it	(which is) a clear view of subject	will help to write essays	
			(which is) a view from different angles	will help to understand topic	
			(which is) exploring from different angles	to give answers to go out an find more information	Example: I could say why has this been put over like this
					confirmed it was just one view
This (example) made me realise that I wasn't wrong	allowed me to look at other people's views	gave me a better picture	gave me more to write about		
			I could explore other views		
			gave me other areas to look at		
			made me more comfortable in writing about something that wasn't said in lecture		
I CAN'T DRAW A DIAGRAM	I CAN'T VISUALISE THINGS ON PAPER				

Table 2. Levels of complexity codes

Implicit	Statements *Doing X helps me to learn*
	Elaborated statements *X involves ….*
Explicit	Implications *Doing X has effect Y*
	Explicit links to theory, technical vocabulary *My learning style is…*
Theory negative	Lack of explicit theory *I don't know how that helps me to learn, it just does.*

Table 3. Self-regulation processes in Sam's transcript.

Forethought	Performance/volitional control	Self-reflection
	Explore	[It's to] satisfy me
Clarify aims	Listen	It's too low level
Follow different pathways	Jot down points	I didn't agree with what they were on about
Find out what they're trying to teach	Is that right	It's only one point of view
Look beyond	Gave more to write about	Made me realise that was fine.. it wasn't that I was wrong
Ask why they are discussing it from that angle	More areas to look at	Gave me a better picture
Get a big picture	I'm a bit wary, maybe I'm wrong	Made me feel more comfortable
View from different angles	I take things on board	I can't draw [a diagram of learning process]
That will help with writing and understanding and finding more information	Listen to what people have said	I can't visualise things on paper
I have an understanding of what is expected	I interpret what has been said	I realise it comes from my viewpoint
	Work out what is their point of view	Didn't have the full information
	Work out where they're getting their information from	I don't know how [slotting in helps my learning]
	Work out how I feel	I don't know [how judging helps]
	Slot it into my thinking	I learn through talking about things
	Give it a value system	It's something that has worked for me for forever
	Make a judgement	It's something that's just there, something I like
	I'm thinking when I'm listening	My learning style is
	See how the tutor reacts	Understanding is a workable knowledge
	I'm thinking too much in the wrong way	
	Judging how it's been received	
	Changing my opinion	
	Questioning	
	Getting feedback	
	It clears my mind	
	I can use the information appropriately	
	When I'm writing I'm discussing it with others	

Table 4. Structure of Sam's mini-theories about how discussion affects his learning

Mini-theory about discussion

Discussion
- Allows me to develop a big picture which is clear and multi-angle
  - Which benefits my writing (issues), understanding, and further study
  - Which makes me more comfortable about what I think
- Allows me to take information on board
  - And sort the information on relevance
  - And interpret what is fact, what is opinion
  - And slot information into my thinking
    - Involves give information a value system
    - And making a judgement about worth of other views
    - And judging how it is received by the lecturer, judging whether I am thinking in the right way

Mini-theory of learning style

Learning style
- I've always learned through talking about things
- This has just worked for me, forever
- It's something that's just there for me …because it's something I like
- Learning style " is a sort of cycle"
  - Questioning → getting feedback → re-questioning → getting feedback

Figure 2. Map showing links between Sam's mini-theories.

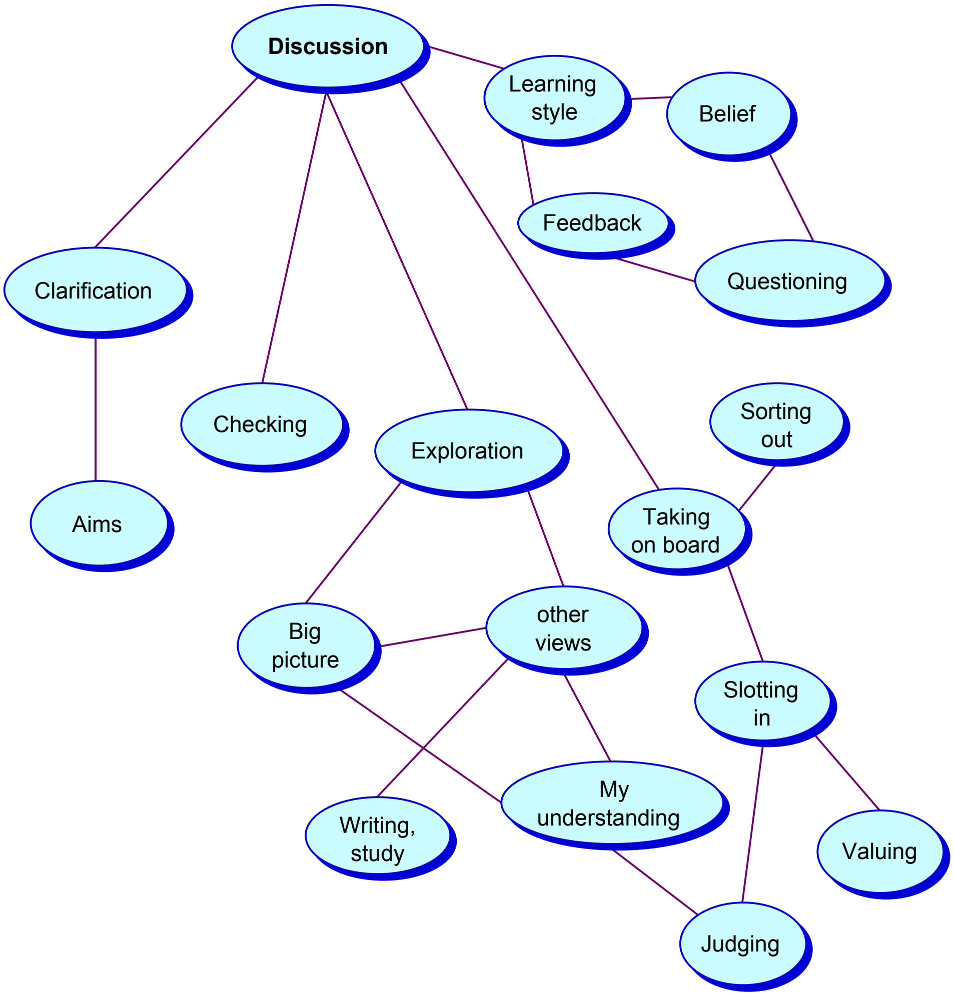

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Table 5. Complexity analysis of Sam's explanations about how discussion helps learning.

Implicit	Statements *Doing X helps me to learn*	26.5 %
	Elaborated statements *X involves ....*	28.6
Explicit	Implications *Doing X has effect Y*	36.7
	Explicit links to theory, technical vocabulary *My learning style is…*	2.0
Theory negative	Lack of explicit theory *I don't know how that helps me to learn, it just does.*	6.1

Table 5. Use of technical language by interviewed students

SRL Terms	Use (N=10)	Other theoretical terms	Use (N=10)
Goal setting	0	Metacognition,	1
Related terms	2	*Related terms*	5
Plan	1	Learning strategy, learning process	4
Related terms	1	*Related terms*	8
Self-efficacy	0	Constructivism, constructivist	1
Related terms	1	*Related terms*	7
Goal orientation	0	Image, imagery, mental image	3
Related terms	2	*Related terms*	2
Intrinsic interest	0	Self-efficacy, attribution	0
Related terms	1	*Related terms*	10
Attention focussing	0	Community of learners	0
Related terms	3	*Related terms*	10
Self-instruction & imagery	3		
Related terms	3		
Self-monitoring	0		
Related terms	1		
Self-evaluation	0		
Related terms	1		
Attributions	0		
Related terms	0		
Self-reactions	0		
Related terms	0		
Adaptivity			
Related terms			